An operational tool for eruption forecasting and short-term probabilistic volcanic hazard for tephra fall: the case of Campi Flegrei (Italy)

Paolo Perfetti (1) *(paolo.perfetti@ingv.it)*, **Jacopo Selva (1), Laura Sandri (1), Giovanni Macedonio (2), Roberto Tonini (3), Luca D'Auria (2), Antonio Costa (1)**

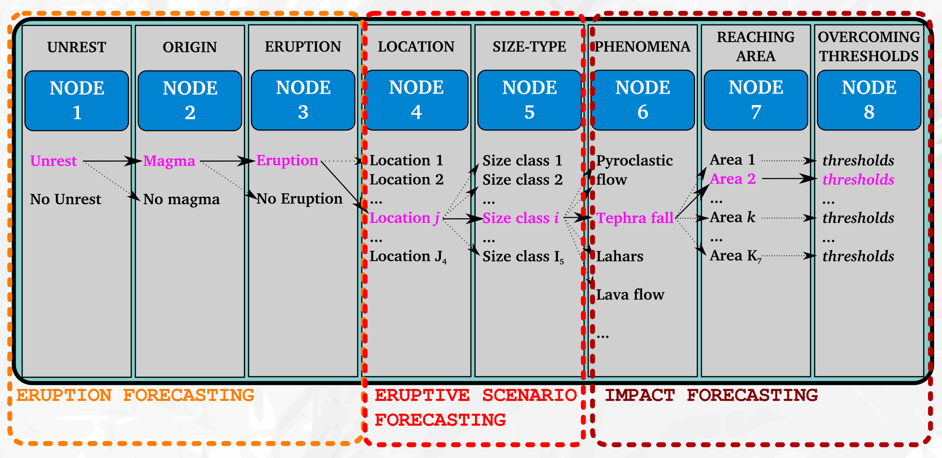
(1) INGV, Bologna (2) INGV-Osservatorio Vesuviano, Napoli (3) INGV, Roma

Introduction to BET-Tephra

BET-Tephra@OV is a Python software package to compute and visualize long- and short- term eruption forecasting and probabilistic tephra hazard assessment of Campi Flegrei caldera. The tool is based on the procedure described by Selva et al. (2014) that combines the Bayesian Event Tree method (Marzocchi et al. 2008; 2010) and on the Fall3D tephra dispersal model (Costa et al. 2006; Folch et al., 2009).

The Bayesian Event Tree model

BET is a probabilistic model that merges all kinds of volcanological information from theoretical/empirical models, geological and historical data, and monitoring observations to obtain probability of any relevant volcanic event. Such probabilities represent an homogeneous and quantitative synthesis of the present knowledge about the volcano.
Dealing with aleatory and epistemic uncertainties BET does not rule out any possibility, but it shapes the probability distribution of the event considered around the most likely outcome accounting for all the information reported above. BET estimates short- and long-term EF, depending on the present state of the volcano.

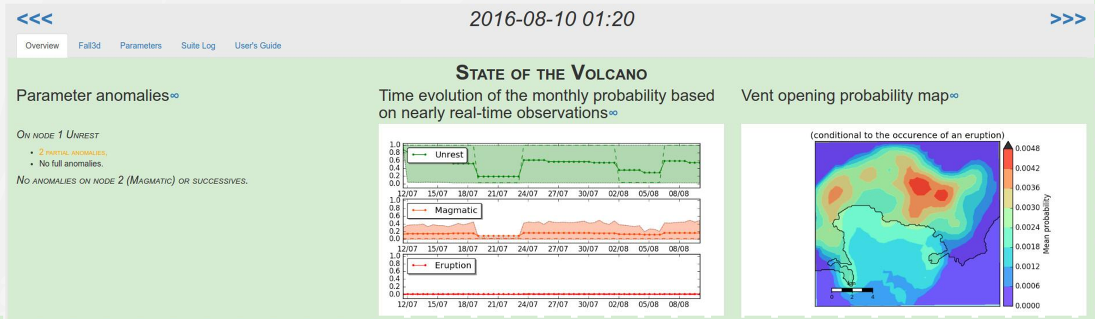


State of the Volcano

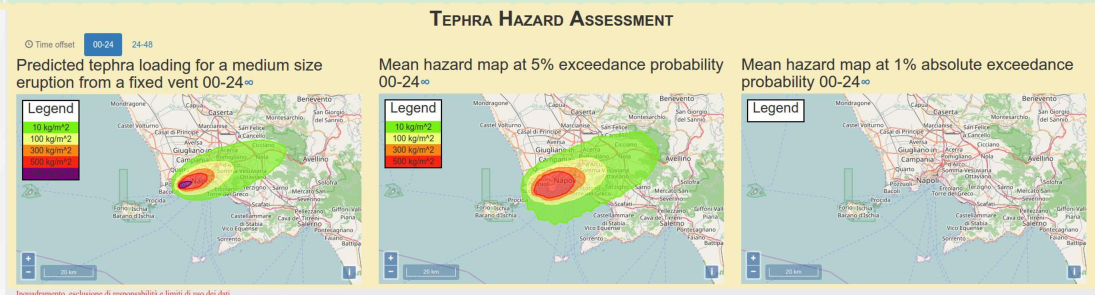
Temporal evolution of conditional probabilities for Unrest, Magmatic Unrest, and Eruption for the last 30 days, computed adopting the method presented in Selva et al. (2012a) with the elicitation parameters updated in 2015. The values refer to the monthly absolute probabilities of each node.

Conditional probability map of vent opening locations, based on the statistical mixing of the short- and long-term maps.

Summary of the anomalies in the monitored parameters



Tephra Hazard Assessment



Predicted tephra loading plot shows the tephra loading associated to a medium size eruption from the caldera centre simulated using the Fall3d model.

Mean hazard map at 5% of conditional exceedance probability (conditional to the occurrence of one eruption of whatever size in whatever vent position) calculated over the selected 24 hours interval.

Mean hazard map at 1% of absolute exceedance probability calculated over the selected 24 hours interval.

Configuration and parameters

BET-Tephra configuration is splitted two parts. The "static part" is stored in a ini-like file and specify the Bayesian Event Tree structure and variables, the runtime directories and programs configuration. The other part of configuration, the dynamic part, is stored in the database and consists in the geophysical parameters along with their type, thresholds and weight therefore allowing the dinamic modification of the BET Eruption Forecasting nodes.

Eruption and Scenario Forecast

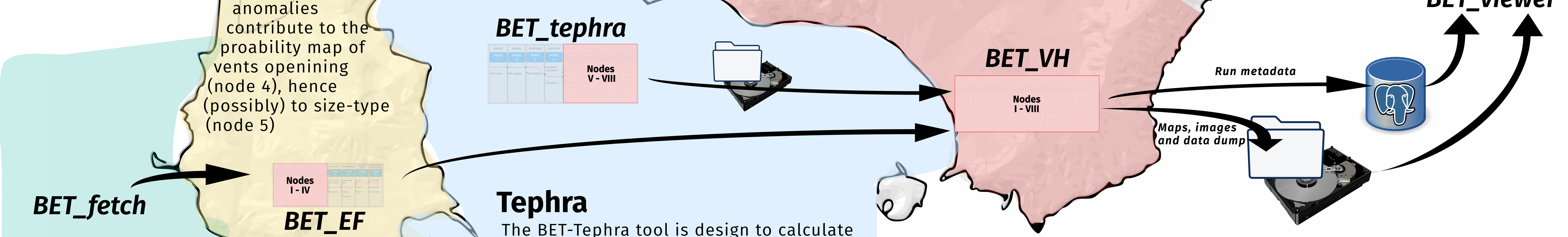
During a quiet period of the volcano, EF is estimated by accounting for the past activity of the volcano (long-term EF). Conversely, during unrest, the method allows mid- to short-term EF to be estimated by considering different patterns of pre-eruptive phenomena. Unrest phase is indentified on the base of parameters anomalies as defined in the elicitation and an unrest_degree is calculated and subsequently used as short term weight in the statistical mixing function for the following BET nodes. Moreover georeferenced anomalies contribute to the proability map of vents opening (node 4), hence (possibly) to size-type (node 5)

Volcanic Hazard

This script produces a quantitative assessment of the probability of exceedance of any potential level of intensity for tephra load hazard due to eruptions within short, configurable time window (hours to days) in any area surrounding the volcano, accounting for all natural and epistemic uncertainties. Freshness of monitoring data, weather data and tephra dispersion simulation results are used to compute the weights used in the statistical mixing between theoretical models, simulations data and short-/long-term analyses and explicitly evaluate aleatory and epistemic uncertainties.

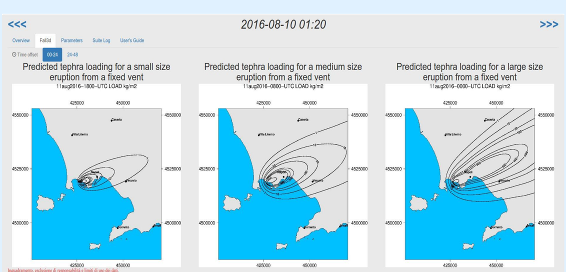
Visualization

To ease the integration in the existing infrastrucures, user inteface is based on web technologies like the microframework Flask. Different representation are defined in a responsive design to provide both interactive maps and static alternative without any external dependency.



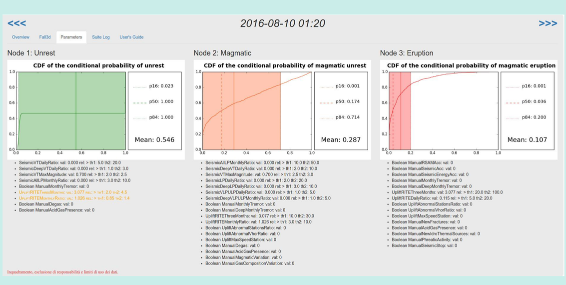
Tephra

The BET-Tephra tool is design to calculate hazard assessments on the base of a multimodel computation even if as now the Fall3d model is the only taken in account. Weather forecast data for the successive 72 hours are downloaded from the ARPA servers at 12 hours interval and scenarios for fixed location and 3 size classes are simulated. Fall3d simulations represents one of the main CPU-intensive tasks and therefore dedicated Celery worker are defined to divide workload among cluster nodes. Simulations are executed as standalone programs without any dependencies by the monitoring parameters, allowing BET-Tephra users to easily define any additional or replacement tephra dispersion model.

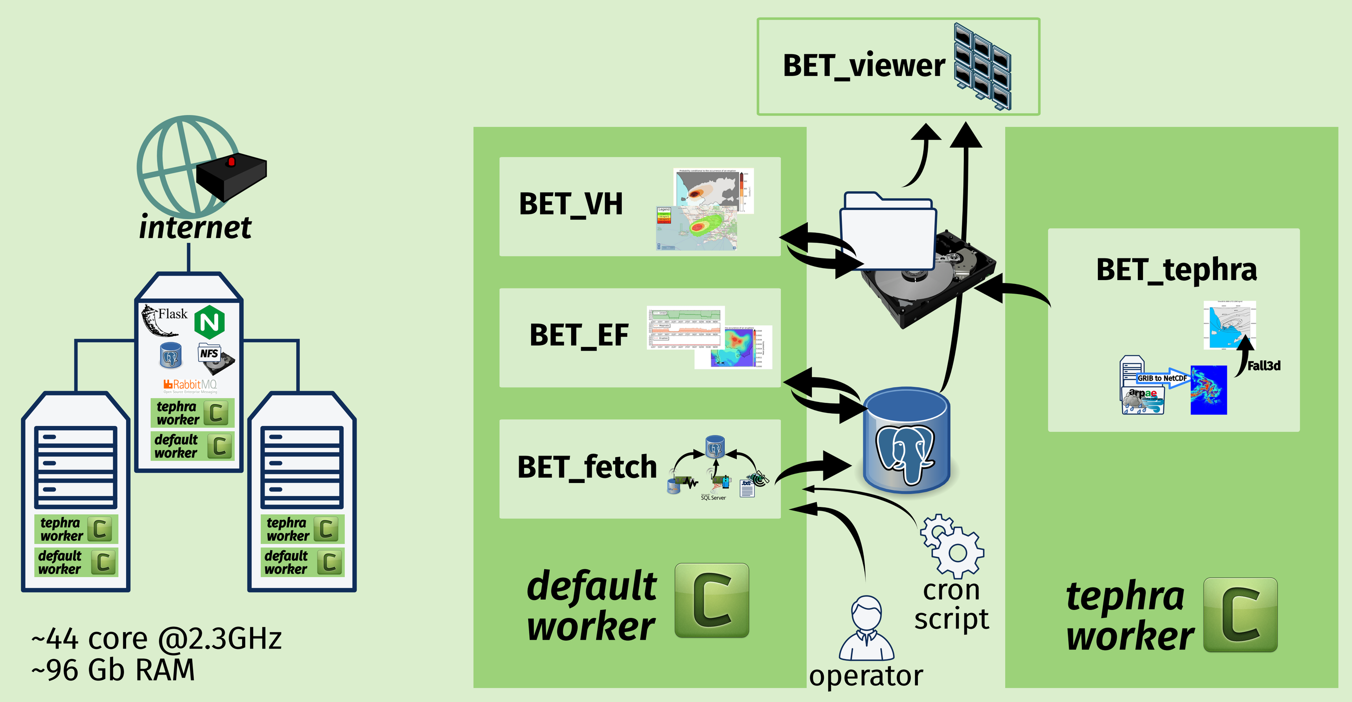


Data acquisition

Campi Flegrei monitoring data is acquired by sensors and it stored databases and filesystem locatedin the INGV-Osservatorio Vesuviano datacenter, locally to where the Monitoring Room for the Naples area is located. Data is fetched and consolidated in a synchronous way(typically every 24 hours) by a dedicated script and stored in a specifically designed PostgreSQL database via the abstraction layer provided by SQLAlchemy ORM. As parameters indentified by the elicitation are often based on the same geophysical measure (seismic events, uplift, etc), Python classes are defined for each MetaParameter and they are responsible for the collection of raw data from the data acquisition infrastructure only once for all related parameters.



Cluster and tasks overview



Acknowledgments

BET_Tephra@OV was realized by Dr. Perfetti with the contributions by Dr. Costa, Dr. Selva, Dr. Sandri, Dr. Macedonio, and Dr. Tonini, in the framework of the Italian Civil Protection Department (DPC) - INGV Research Project "OBIETTIVO 5 (V2): Implementazione nell'ambito delle attività di sorveglianza del vulcano Campi Flegrei di una procedura operativa per la stima in tempo quasi reale della probabilità di eruzione, probabilità di localizzazione della bocca eruttiva, e probabilità di accumulo delle ceneri al suolo in caso di eruzione di tipo esplosivo", 2014-2015 (Responsible Dr. Giuseppe De Natale, Director of INGV - Osservatorio Vesuviano, Napoli), under the Coordination of Dr. Antonio Costa (INGV, Bologna).

About me

Paolo Perfetti is a Research Fellow at INGV -Sezione di Bologna. MSc in Computer Science, he began to work at INGV in 2008 as System Administrator on HA /HPC clusters. After one year as Telecommunications Expert in the French-Italian research station Concordia in Antarctica, he started the current fellowship mainly as Python programmer on hazard and risk assessment topics. He is now developing the Probabilistic Tsunami Hazard Assessment Python implementation to be included in the Italian Tsunami Early Warning System for the Mediterranean Sea.

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA
INGV terremoti vulcani ambiente

PUERTO VARAS, CHILE 2016
Cities on Volcanoes 9

References

Costa A., Macedonio G., Folch A. (2006) A three-dimensional Eulerian model for transport and deposition of volcanic ashes. Earth Planet. Sci. Lett., 241, 634/647, doi: 10.1016/j.epsl.2005.11.019
Folch A., Costa A., Macedonio G. (2009) FALL3D: A Computational Model for Volcanic Ash Transport and Deposition, Comput. Geosci., 35, 1334-1342, doi:10.1016/j.cageo.2008.08.008
Marzocchi W, Sandri L, Selva J (2008). BET_EF: a probabilistic tool for long- and short-term eruption forecasting, Bull. Volcan., 70, 623-632, doi:10.1007/s00445-007-0157-y
Marzocchi W, Sandri L, Selva J (2010), BET_VH: a probabilistic tool for long-term volcanic hazard assessment, Bull. Volcanol., 72 (6), 717-733, doi:10.1007/s00445-010-0357-8
Selva J., Costa A., Sandri L., Macedonio G., Marzocchi W. (2014) Probabilistic short-term volcanic hazard in phases of unrest: a case study for tephra fallout, J. Geophys. Res., 119 (12), 1-22, doi:10.1002/2014JB011252
Selva J, Marzocchi W, Papale P, Sandri L (2012a), Operational eruption forecasting at high-risk volcanoes: the case of Campi Flegrei, Naples, J. Applied Volcanology, 1:5, doi:10.1186/2191-5040-1-5
Selva J., Orsi G., Di Vito M.A., Marzocchi W., and L. Sandri (2012b). Probability hazard map for future vent opening at the Campi Flegrei caldera, Italy. Bull Volcanol, 74:497–510, doi:10.1007/s00445-011-0528-2.